Neural oscillations in the perception of audiovisual synchrony

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Introduction

1. One crucial aspect of multisensory perception is the perception of intersensory synchrony – that is, when two sensory inputs come from one and the same multisensory source (say the lip movements and articulated sounds from a speaker) they should be perceived as being synchronous, despite the existence of intersensory lags.
2. It has been established that crossmodal stimulus pairs are perceived to be synchronous within a temporal window of up to several hundred ms, depending on stimulus parameters (Vroomen & Keetels, 2010)
3. We hypothesize that the existence of perceptual (8-12 Hz) and/or attentional (4-7 Hz) cycles (VanRullen, 2016) constitutes (one of) the neural mechanism(s) that underlies the notion of a temporal window of integration.
4. If so, we would expect simultaneity judgements of visual and auditory stimuli, under certain conditions, to be dependent on the phase of posterior alpha and theta oscillations, as these oscillations are thought to reflect perceptual and attentional cycles, respectively.

Methods

Task and behavioral data

64-channel EEG was recorded from 33 participants while they performed a simultaneity judgement task of visual and auditory stimuli (visual first), with SOAs ranging from 0 to 360 ms. Behavioral data are shown in Figure 1.

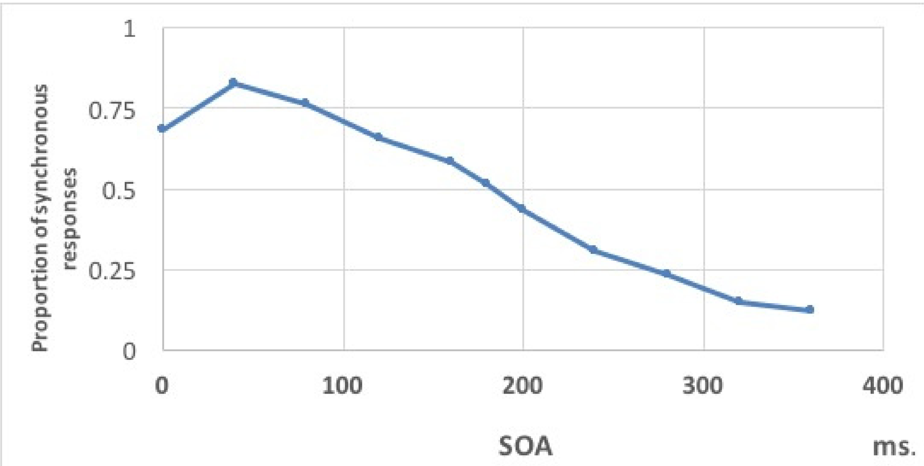


Figure 1. Grand average (final participant set, N=22) behavioral data from the simultaneity judgement task. At SOAs 160, 180 and 200 ms judgements were most evenly distributed for these participants.

As we were mostly interested in the cognitive and perceptual processes around the point of subjective simultaneity, for each participant we selected the SOA for which the synchronous and asynchronous judgements were most evenly distributed across trials. We then verified whether the proportion of synchronous and asynchronous judgements for this SOA was in between 0.3 and 0.7 (or 0.7 and 0.3). For 22 out of the 33 initial participants, these criteria were met. The EEG data from all other participants, and all other SOAs were excluded from further analysis.

EEG data analysis

- ERP analysis
- Time-frequency analysis of power
- Time-frequency analysis of inter-trial coherence (ITC)
- Phase-dependency of responses. For this analysis, crucial to our hypothesis, trials were first separated into 6 equally spaced phase bins. For each of these bins, the proportion of asynchronous judgements was computed. The bin with the largest proportion of asynchronous responses was arbitrarily defined as zero phase angle for each participant (cf. Baumgarten et al., 2015).

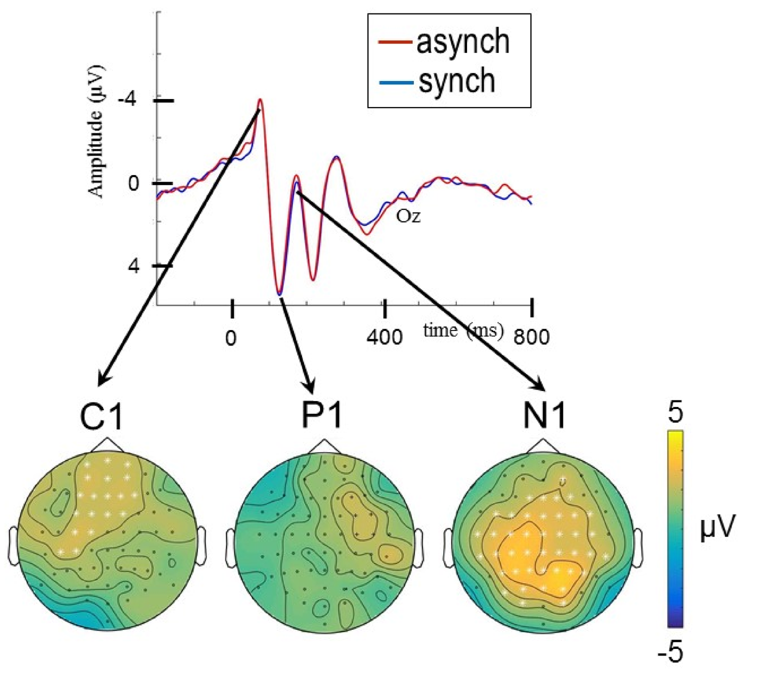
Statistical analysis

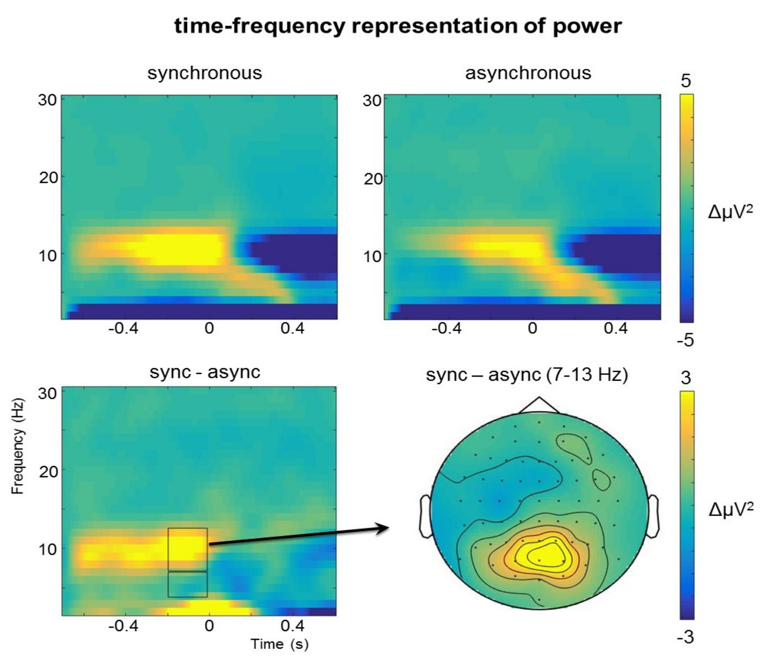
For ERPs, power and ITC data, we used cluster-based random permutation statistics (Maris & Oostenveld, 2007) . For the phase-dependent analysis, we used ANOVA's and t-tests.

Results

ERP

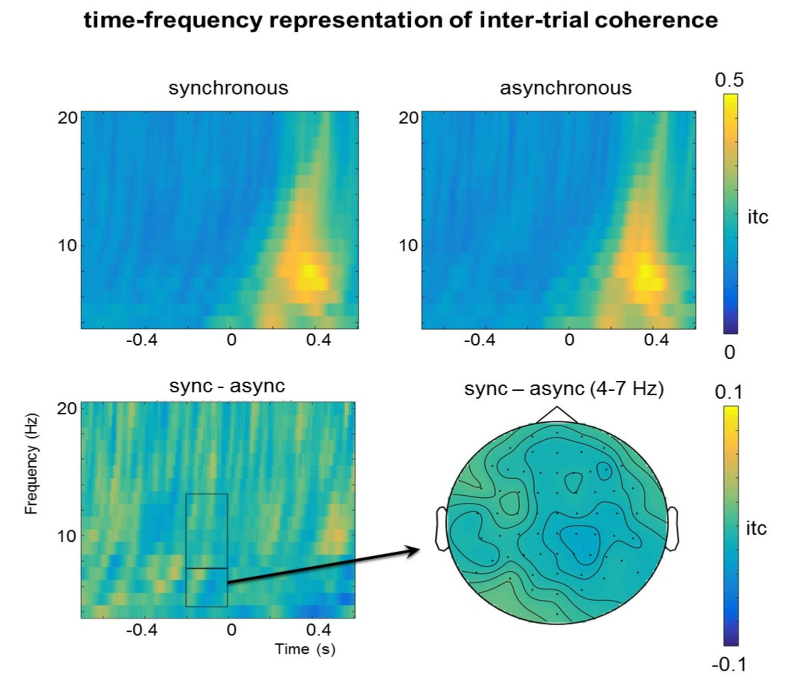
larger C1 and larger N1 for trials with asynchronous responses





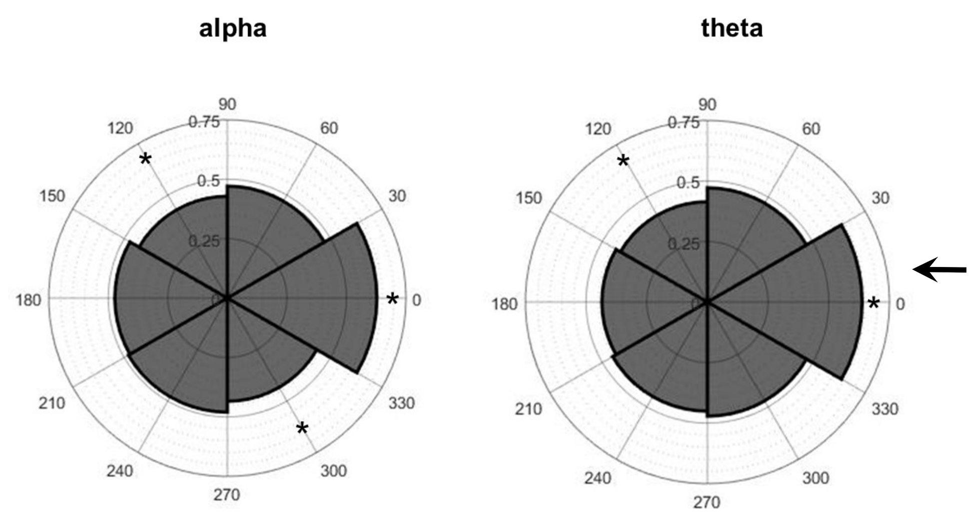
Power

larger alpha power for trials with synchronous responses



ITC

larger theta coherence for trials with asynchronous responses



Phase dependence

- 0° phase bin more async responses (alpha and theta)
- 120° phase bin more sync responses (alpha and theta)
- 300° phase bin more sync responses (alpha)

Discussion

1. ERPs and power changes suggest that accurate judgements (i.e., asynchronous responses) coincide with moments when the visual cortex is in a state of readiness.

- Larger C1 in the ERP → stronger activation of visual cortex
- Larger N1 in the ERP → higher level of attention
- Less alpha power over occipital areas → less inhibitory activity in visual areas

2. Crucially, phase analysis shows that simultaneity judgements are dependent on the phase of alpha and theta oscillations. This provides support for the hypothesis that perceptual and attentional cycles are at the basis of a temporal window of integration in multisensory synchrony perception.

- Higher ITC for theta oscillations on trials with asynchronous responses is not very convincing (though significant)
- Phase binning clearly shows that simultaneity judgements are more accurate (more asynchronous judgements) at certain phases of alpha and theta oscillations, and less accurate (more synchronous judgements) at other phases. There is hardly any differentiation between alpha and theta, though.

References

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